TECHNICAL REPORT ARBRL-TR-02590

ACCEPTANCE TESTING OF THE MODEL 2023 HOT WIRE DETONATOR

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
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This report describes the specifications, testing procedures and results for the model 2023 hot-wire detonator. Then detonator is similar to the ARC-211 detonator, which it replaces. Its functioning time using 5000 volts, 1μFd capacitance and 15 ft of RG58A/U cable is 3.35 μsec.

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I. INTRODUCTION

In 1963 and 1968 the Ballistics Research Laboratory contracted with the Flare Northern Division of the Atlantic Research Corporation (ARC) to develop an improved M36A1 hot-wire detonator. The improved detonator was to have a more precise functioning time for synchronization with high speed recording instrumentation and to be insensitive to ignition by static discharge from the human body. These objectives were attained and the results documented in BRL reports.[1,2]

The improved detonator was called the ARC-211. Recently the supply of these detonators had become almost exhausted and a contract was awarded to TRACOR MB Associates, East Camden, Arkansas, to manufacture 5000 hot wire detonators as similar to the ARC-211 as practically feasible. This report presents our requirements for the present detonator, the acceptance testing procedures, and the results of acceptance testing. The testing procedures and requirements were basically those of References 1 and 2. The replacement detonator is called Model 2023.*

II. SPECIFICATIONS

The specifications for Model 2023 were basically the same as those for the ARC-211 detonator given in the above references. A brief summary of the main requirements is given here. For more detail see References 1, 2,and 3.

A. Type

The detonators shall be insensitive to static electricity and suitable for precision synchronization. They shall be completely sealed units. They shall be two-wire electric detonators with a diameter of 0.280" ±0.010" and length of 0.500" to 0.850".

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[1] *Caudill, G. H., Taylor, B. C., Melani, G., BRL Memorandum Report No. 1684, August 1965 AD477112.*

[2] *Taylor, B. C., Melani, G., BRL Memorandum Report No. 2096, February 1971, AD726903.*

* *It is recommended that an exploding bridgewire detonator be used whenever possible since it is inherently less sensitive than a hot-wire detonator. There may be situations, however, that preclude the use of exploding bridgewire detonators; for example, when the high voltage firing pulse would cause unwanted signals on measurement instrumentation.*

[3] *Contract DAAD05-82-C-0092.*

B. Output

The detonators shall contain a base charge sufficient to detonate a bare booster pellet of cold-pressed, plastic-bonded RDX having a density of 1.57 g/cc.

C. Functioning Time

The detonators shall be constructed so that the detonator functioning time is less than 3.0 microseconds at 5KV with 15 ft. of RG58A/U cable. The major requirement is that the estimated standard deviation be less than 0.15 microseconds at 5KV with 15 feet of RG58A/U cable.

Additional requirements are that the detonators function satisfactorily with an increase in functioning time of no more than 0.30 microseconds when the voltage on the test set is decreased to 3.0KV using a 15 foot lead of RG58A/U cable to the detonators.

The increase in functioning time shall be no more than 1.0 microsecond when two detonators are fired in parallel with 5KV on the test set using a single 50 foot lead of RG58A/U cable to the two detonators.

The detonators shall also function satisfactorily with a six volt dry cell battery or with a blaster's handgun.

D. Voltage Limits

The detonators shall be constructed with sufficient insulation and clearances so that flash over or voltage breakdown does not occur in standard atmosphere from sea level to 2000 ft., for temperature range from 20 degrees F to 100 degrees F, and relative humidity from 30 percent to 100 percent.

For safety in handling, these detonators shall not explode when connected to 0.5 volt rms, ac or dc, (measured across detonator leads) for 60 seconds or when carrying a current of 0.5 amp rms, ac or dc for 60 seconds.

E. Electrostatic Sensitivity

The detonators shall be manufactured so that application of a series of three test electrostatic discharges between either of the bridgewire leads and the metal detonator shell shall not cause the detonator to explode. The test electrostatic discharge shall be generated by discharging a 500 picofarad capacitor charged to 20,000 volts, by means of a vacuum contactor. The two electrical leads connecting the detonator to this circuit shall consist of the insulated core of RG58A/U cable and shall be 6 feet or less in length.

III. TESTING

Preproduction testing was done on three lots of detonators. All tests were done in a blast chamber. The following tests were performed:

1) A resistance measurement of the conductive path between the detonator cup and the bridgewire leads. This conductive path inhibits buildup of

electrostatic voltage between the detonator cup and the bridgewire leads thereby preventing a possible spark discharge within the detonator.

2) Electrostatic Sensitivity - see Introduction.

3) Functioning Time - see Introduction.

4) Steady Current Threshold - see Voltage Limits in Introduction.

A. Preproduction Lot I

1. Resistance Measurement of Conductive Path. A blasting galvonometer was used to measure the resistance of the conductive path between the detonator cup and the bridgewire leads. One test lead of the galvanometer was attached to the detonator cup by an alligator clip. The detonator was then placed inside a detonator carrying box (1/2" plywood construction) with the twisted detonator leads and the galvonometer lead extending out between the clamped lid and the box. The other galvanometer lead was then connected to the twisted detonator leads; the resistance of the conductive path was read on the galvanometer. For expediency, the first lot of detonators we tested had a conducting path made with a paste of 20 micron aluminum powder and acetone. The detonator leads had cloth insulation; on one lead the insulation in the vicinity of the conducting path had been scraped away in an attempt to obtain continuity between the detonator lead and the conducting path.

Detonator Number	Resistance of Conducting Path (ohms)
1	∞
2	∞
3	∞
4	∞
5	∞
6	∞
7	∞
8	∞
9	∞
10	∞

As can be seen, the galvanometer readings were infinite indicating a break in the conductive path. However, as noted in Reference 2, even a disrupted path breaks down under high voltage and provides a safe discharge path for static charge. It was requested that future test lots have bare detonator leads and silver conducting paint in order to establish a good conducting path.

2. Electrostatic Sensitivity. The circuit shown in Figure 1 was used to discharge a 500 picofarad capacitor between the detonator cup and the twisted detonator leads. The 500 picofarad capacitor in series with zero ohms is a conservative human body equivalent. The maximum charging voltage was 20KV. A series of three discharges was made across each detonator.

Detonator Number	Discharge Voltage (K volts)	Results X=Go O=No Go
1	8, 10, 20	0, 0, 0
2	20, 20, 20	0, 0, 0
3	20, 20, 20	0, 0, 0
4	20, 20, 20	0, 0, 0
5	8, 12, 16, 20, 20, 20	0, 0, 0, 0, 0, 0
6	20, 20, 20	0, 0, 0
7	20, 20, 20	0, 0, 0

As anticipated the conducting path, though disrupted, provided a safe discharge path for 500 picofarads charged to 20KV.

3. Functioning Time. The functioning time of the detonator was determined by using the circuit shown in Figure 2. A trigger pulse fires the high voltage unit and starts the digital oscilloscope. The high voltage discharge monitor pulse is fed into channel A of the digital oscilloscope. When the detonation front, established in the PBX pellet, shorts out the twisted wire pair, a signal is sent to channel B. An oscilloscope record is shown in Figure 3. The upper trace corresponds to channel A and the lower trace to channel B. The interval between the positive signals is measured. This measurement represents the time for the detonator to function plus the time for the detonation wave to traverse the PBX pellet. When the traversal time of 1.7 microsecond is subtracted from the total we get the detonator functioning time. These times are shown below for several firing conditions.

Firing Conditions	Detonator Number	Functioning Time (μsec)
1μFd	1	3.175
5000 volts	2	3.125
15 ft. RG58A/U Cable	3	3.175
single det.	4	3.125
	5	3.175
	6	3.075
avg. func. time = 3.12 $\pm$ .05μsec	7	3.075
	8	3.075
	9	3.075
	10	3.075

Firing Conditions	Detonator Number	Functioning Time (μsec)
1μFd	11	3.425
3000 volts	12	3.375
15 ft. RG58A/U Cable	13	3.275
single det.	14	3.325
	15	3.325

avg. func. time = 3.35 $\pm$ .06 sec

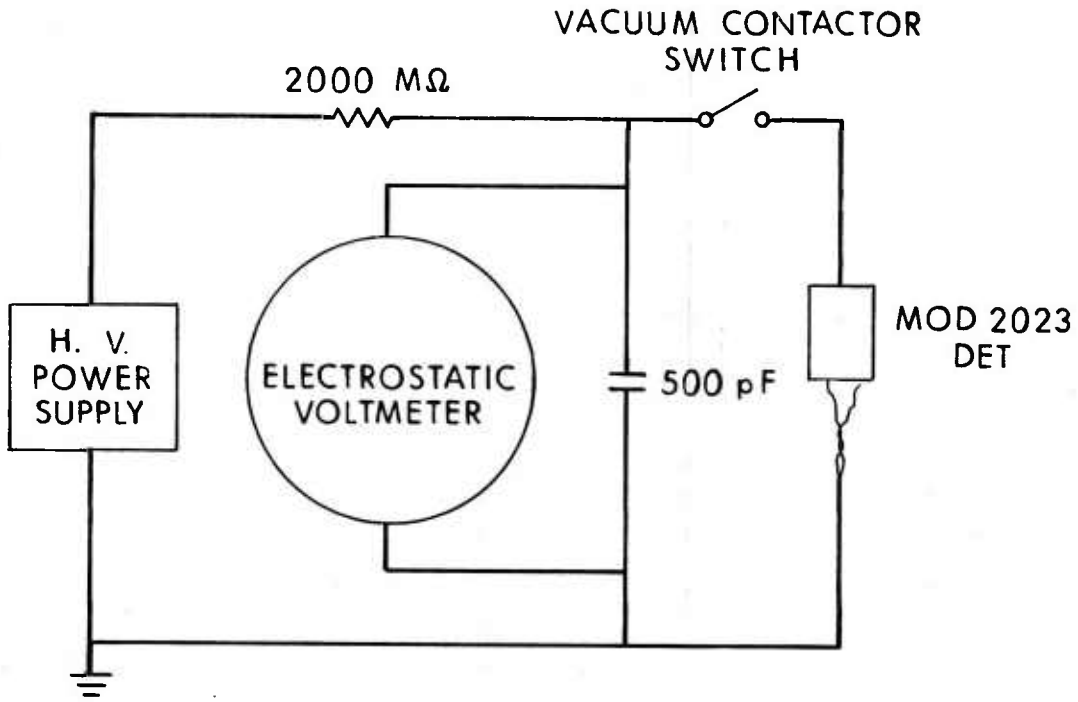

Figure 1. Electrostatic Sensitivity Test Circuit

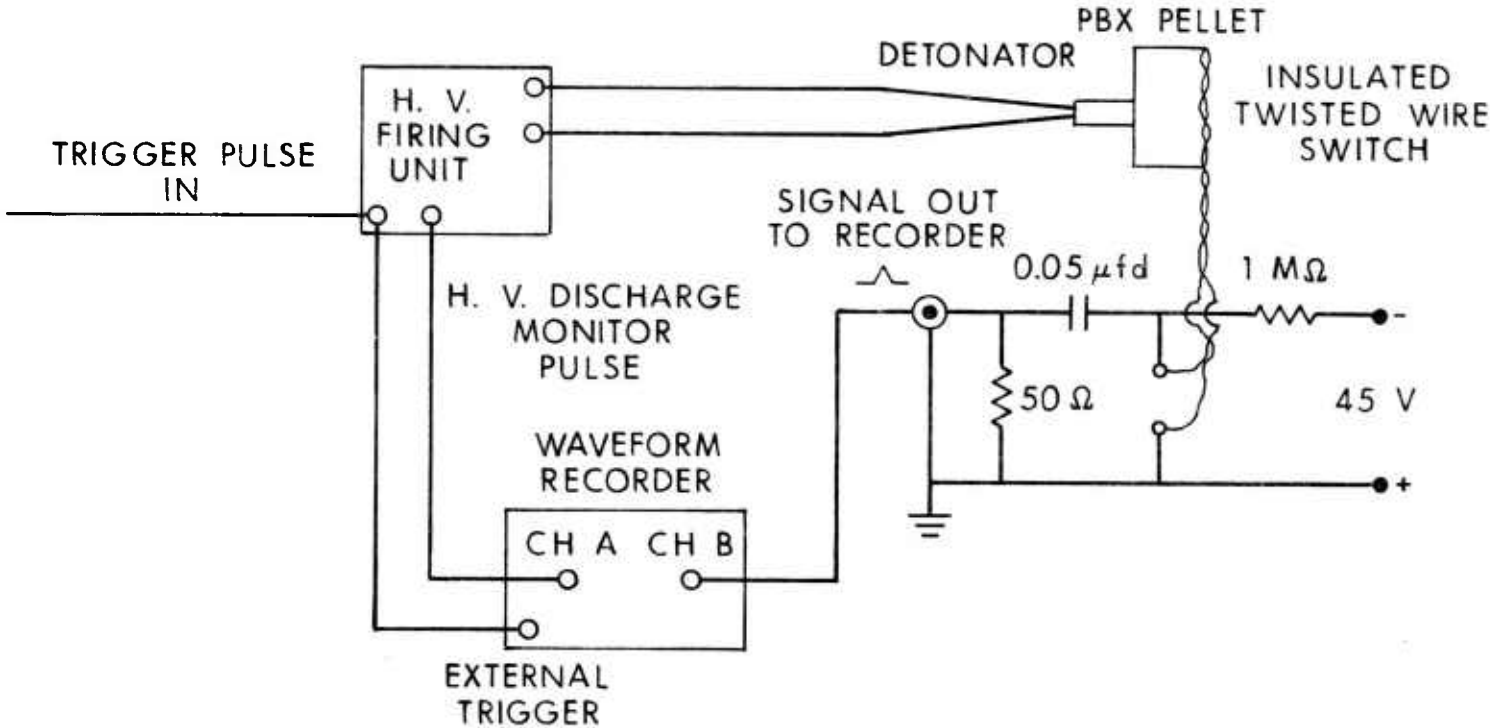

Figure 2. Functioning time test circuit. A 52 ohm terminator was used on all inputs to the waveform recorder.

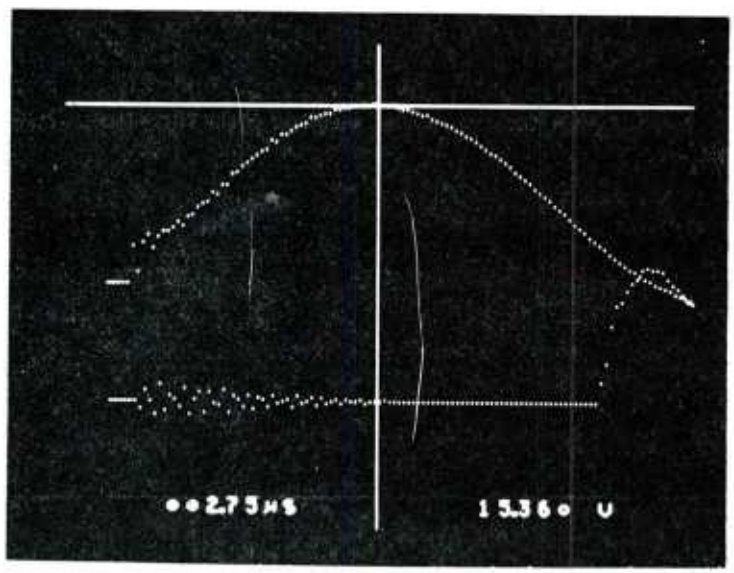

Figure 3. Digital oscilloscope record showing the high voltage discharge monitor pulse on the upper trace and the signal from the twisted wire circuit on the lower trace. (50 nanosecond resolution)

Firing Conditions	Detonator Number	Functioning Time (μsec)
1μFd	16	3.875
5000 volts	17	3.675
50 ft. RG58A/U Cable	18	3.725
2 dets. in parallel	19	3.825
	20	3.775

avg. func. time = 3.78 ± .08μsec

4. Current Threshold. A dc power supply was connected by 15 ft. RG58A/U cable to the detonator leads and the voltage was varied until a current of 0.5 amperes flowed through the detonator bridgewire. The current was held at this value for 60 seconds and then it was slowly increased until the detonator exploded. The results are shown below.

Detonator Number	Steady Current (1/2 amp for 60 sec)	Explosion Current (amp)
21	No Go	0.7
22	No Go	0.7
23	No Go	0.7
24	No Go	0.7
25	No Go	0.7
26	No Go	0.7
27	No Go	0.7
28	No Go	0.7
29	No Go	0.7
30	No Go	0.7

B. Preproduction Lot II

1. Resistance Measurement of Conducting Path. The detonator leads in this lot still had cloth insulation on them but silver conducting paint[4] was used instead of aluminum paste for the conducting path.

[4] *Silver paint No. 5002, SPI Supply, Westchester, PA.*

Detonator Number	Resistance of Conducting Path (ohms)
1	100
2	0
3	0.5
4	2.5
5	0.5
6	7
7	0
8	0
9	0
10	0.5
11	10
12	1
13	0
14	0.5
15	2
16	∞
17	7
18	10
19	1
20	0

2. Electrostatic Sensitivity.

Detonator Number	Discharge Voltage (K VOLTS)	Results X = Go O = NoGo
1	20, 20, 20	0, 0, 0
2	20, 20, 20	0, 0, 0
3	20 20, 20	0, 0, 0
4	20, 20, 20	0, 0, 0
5	20, 20, 20	0, 0, 0
16	20, 20, 20	0, 0, 0

3. Functioning Time.

Firing Conditions	Detonator Number	Functioning Time (μsec)
1μFd	1	3.025
5000	2	3.325
15 ft. RG58A/U Cable	3	3.075
Single Detonator	4	3.225
	5	3.125
avg. fun. time = 3.17 ± .11μsec	16	3.167

C. Preproduction Lot III

1. Resistance Measurement of Conductive Path.

The detonators in this lot had bare detonator leads so that a better

conducting path could be made between a detonator lead and the cup. Silver paint was used for the conducting path.

Detonator Number	Resistance of Conducting Path (ohms)
1	1
2	1
3	0
4	0
5	3.5
6	0
7	70
8	1
9	0
10	17
11	1.4
12	0
13	0
14	0.3
15	0
16	10
17	0.2
18	1
19	1
20	1

2. Electrostatic Sensitivity.

Detonator Number	Discharge Voltage (KVolts)	Results x = GO, 0 = No Go
1	20	0,0,0
2	20	0,0,0
3	20	0,0,0
4	20	0,0,0
5	20	0,0,0
6	20	0,0,0
7	20	0,0,0
8	20	0,0,0
9	20	0,0,0
10	20	0,0,0

3. Functioning Time.

Firing Conditions	Detonator Number	Functioning Time (μsec)
1 μ Fd.	1	3.125
5000 volts	2	3.075
15 ft RG58A/U cable	3	3.125
single det.	4	3.125
	5	3.175

Avg Func Time = 3.13 $\pm$ .04μsec

4. Current Threshold.

Detonator Number	Steady Current (0.5 amp for 60 sec)	Explosion Current (amp)
6	No Go	0.7

D. Production Lot

A total of twenty detonators was randomly selected from the production lot of 5000 for use in the following tests.

1. Resistance Measurement of Conducting Path. Bare lead wires and silver conducting paint were used for the conducting path.

Detonator Number	Resistance of Conducting Path (ohms)
1	20
2	7
3	9
4	5
5	30
6	30
7	3
8	9
9	20
10	20
11	2
12	∞
13	1
14	40
15	5
16	24
17	10
18	16
19	5
20	10

2. Electrostatic Sensitivity.

Detonator Number	Discharge Voltage (K VOLTS)	Results X = Go, O = No Go
1	20	0,0,0
2	20	0,0,0
3	20	0,0,0
5	20	0,0,0
6	20	0,0,0
7	20	0,0,0
8	20	0,0,0
10	20	0,0,0
11	20	0,0,0
12	20	0,0,0
13	20	0,0,0
14	20	0,0,0
15	20	0,0,0
20	20	0,0,0

3. Functioning Time.

Firing Conditions	Detonator Number	Functioning Time (μsec)
1μFd.	1	3.325
5000 volts	4	3.375
15 ft. RG58A/v cable	8	3.625
single detonator	9	3.225
	15	3.275
	16	3.525
avg. func. time = 3.35 $\pm$ .13 μsec	17	3.275
	18	3.325
	19	3.275
	20	3.275

4. Current Threshold.

Detonator Number	Steady Current (0.5 amp for 60 sec.)	Explosion Current (amps)
2	No Go	0.70
7	No Go	0.62
10	No Go	0.66
11	No Go	0.60
14	No Go	0.61

IV. CONCLUSION

The model 2023 detonator was found to be an acceptable replacement for the ARC-211 detonator even though the functioning time of 3.35 μsec was longer than the 3.0 μsec originally specified.

The model 2023 detonator has the following characteristics:

length = .660"
lead length = 7" long bare wire
max. O.D. = .285"
bridgewire = .0017" dia. Secon Alloy #486.
resistance = 0.85 to 1.20 ohms
explosive load 230 mg lead azide dextrinated, ignition charge
300 mg Comp A-5 (RDX + 3% wax), case charge

func. time = 3.35 $\pm$.13 μsec

using 1μFd capacitance,
5000 volts, 15 ft. RG58A/U
cable and a single detonator

1983 cost (lot of 5000) = $7.39 per detonator

V. TEST EQUIPMENT

Digital Oscilloscope - Nicolet Model 2090 with model 204A plug in unit

High Voltage Firing Unit - Reynolds Model FS-19

High Voltage Power Supply - Field Emission Corp. Model No. 214

D.C. Power Supply - Power Designs, Model 5005R

Blasting Galvanometer - Bitronics Inc.

Vacuum Contactor Switch - Jennings Model RE6B - 115N300 115 VDC

Electrostatic Voltmeter - Sensitive Research Equipment Corp. Model ESH

The twisted wire pair was made using no. 30 copper wire with single strand nylon insulation.

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